Step by step: A microgenetic study of the development of strategy choice in infancy

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To examine patterns of strategy choice and discovery during problem-solving of a novel locomotor task, 13.5- and 18-month-old infants were placed at the top of a staircase and encouraged to descend. Spontaneous stair descent strategy choices were documented step by step and trial by trial to provide a microgenetic account of problem-solving in action. Younger infants tended to begin each trial walking, were more likely to choose walking with each successive step, and were more likely to lose their balance and have to be rescued by an experimenter. Conversely, older infants tended to begin each trial scooting, were more likely to choose scooting with each successive step, and were more likely to use a handrail to augment balance on stairs. Documenting problem-solving microgenetically across age groups revealed striking similarities between younger infants’ strategy development and older children’s behaviour on more traditionally cognitive tasks, including using alternative strategies, mapping prior experiences with strategies to a novel task, and strengthening new strategies. As cognitive resources are taxed during a challenging task, resources available for weighing alternatives or inhibiting a well-used strategy are reduced. With increased motor experience, infants can more easily consider alternative strategies and maintain those solutions over the course of the trial.

The field of cognitive development has recently shifted its focus from describing stage-based changes to exploring and understanding the mechanisms underlying change (Adolph, Robinson, Young, & Gill-Alvarez, 2008; Lemaire, 2010; Siegler, 2007). One of the most fruitful approaches has been the microgenetic analysis of variability in how school-aged children choose and execute strategies for solving problems. In these studies, researchers make densely timed observations as children carry out a task, successfully or not, typically in the context of math- or school-related skills (Bull, Espy, & Wiebe, 2008; Lemaire & Lecacheur, 2011; Lemaire & Reder, 1999; Siegler, 2007; Tunteler & Resing, 2002). Siegler’s ‘overlapping waves theory’ lays out the expectations for the typical development of strategy use in contexts such as preschoolers using simple tools and grade-schoolers solving arithmetic problems (e.g.,

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Chen & Siegler, 2000; Lemaire & Siegler, 1995). On this account, studying within-child variability, rather than treating it as noise, is a powerful predictor of and tool for understanding change (Siegler, 2007). Strategy development starts with the acquisition of new strategies, improves as novices become able to map prior experiences to novel tasks, and culminates with the strengthening of newly acquired strategies (see Chen & Siegler, 2000, for a review).

The mechanism for change, or what prompts children to move from less to more efficient and successful strategies, is the automatization that comes from practice. As cognitive resources that had previously been allocated to the monitoring of strategy execution become available, they can be reallocated to make problem-solving more efficient, such as searching for redundancies within existing strategies (Siegler, 2000). Moreover, as practice increases familiarity with a problem, working memory resources can be reallocated to the exploration of alternative strategies (Shrager & Siegler, 1998). Conversely, a decrease in processing resources in the elderly is associated with impaired strategy use compared to younger adults, such as less efficient performance or poor strategy choices (Lemaire, 2010).

One limitation to the typical measurement approaches for studying strategy choice and problem-solving has been an emphasis on verbal and mathematical problems that, while yielding rich behavioural data sets for older children, are generally unsuitable for use with infants (Keen, 2011). As a result, our understanding of the process of strategy acquisition in infancy lacks the level of detail that we have with older children. One domain in which infants provide as rich behavioural data sets as older children is locomotor development. Indeed, studies of how infants solve locomotor problems have revealed that experts in a posture can devise alternative strategies when they encounter situations where their typical strategies are no longer appropriate. For example, expert cruisers can bend at the waist or cruise on their knees to use a low handrail (Berger, Chan, & Adolph, 2014), and expert walkers choose to crawl so they can navigate squishy surfaces (Joh & Adolph, 2006), scoot so they can navigate steep slopes (Adolph, 1997), and turn their bodies sideways to grab a handrail so they can navigate narrow bridges (Berger & Adolph, 2003; Berger, Adolph, & Kavookjian, 2010; Berger, Adolph, & Lobo, 2005).

The overall goal of this study was to better understand the process of strategy choice in young infants. As such, our first aim was to determine whether infants’ patterns of strategy discovery and selection followed the same trajectory as those observed in older children and adults. We designed a locomotor task that could provide a context for observing development in action, particularly the emergence of problem-solving skills. Specifically, we sought to microgenetically document infants’ spontaneous stair descent strategies. Previous work has focused primarily on establishing norms for when infants learn to climb stairs (Frankenburg & Dodds, 1967; Gesell, 1934; McGraw & Breeze, 1941) or the social structures that support infants as they learn to climb stairs (Berger, Theuring, & Adolph, 2007), but we know very little about how infants independently discover new strategies for climbing stairs (Ulrich, Thelen, & Niles, 1990). Documenting infants’ strategies literally from step to step would yield a high-density sample in real time and capture change within and between trials (Siegler, 1996, 2002). Based on parent reports of how infants first learned to descend stairs (Berger et al., 2007), we expected to observe variability in infants’ spontaneous stair descent when stairs were presented as a novel task that would provide a differentiated description of children’s strategy choice (Chen & Siegler, 2000; Siegler, 1996, 2002; Wilmut & Barnett, 2011). For example, in a sample of over 300 families, parents reported that infants typically descended stairs by crawling backwards,
walking while holding a banister, or scooting down in a sitting position (Berger et al., 2007). Moreover, parents reported being actively involved in teaching their infants to climb stairs, including maneuvering infants’ limbs into proper position to demonstrate descent. Allowing infants to solve the novel problem of stair descent independently and without constraint would create a relatively naturalistic situation, generate behaviors to make strategy evolution observable, and circumvent the problem of studying problem-solving in a pre-verbal population (Siegler, 1996, 1998; Ulrich et al., 1990).

Unlike most motor skills acquired in the first 2 years of life, stair descent carries an element of risk. Infants are more likely to fall down stairs than any other age group except elderly adults over the age of 65 (National SAFE KIDS Campaign, 2004; Young, Torner, Schmitt, & Peek-Asa, 2011). Although infants fall frequently when learning to cruise while holding onto furniture or walk on flat ground, they do not typically incur serious injury (Adolph et al., 2012; Sugar, Taylor, & Feldman, 1999). In contrast, approximately 73,000 children between the ages of 6 months and 2 years were injured on stairs or steps in 2009 (U.S. Consumer Product Safety Commission, 2010). The extended period of locomotor experience that is required before infants can coordinate different components of a plan into a strategy or devise alternative strategies may explain the number of injuries associated with falls on stairs, despite parents’ best efforts to teach their children safe descent strategies (Berger et al., 2007). Understanding infants’ strategy choice in the context of stair descent would not only enhance our basic understanding of the development of decision-making in early childhood, but may offer some practical advice to caregivers about children’s learning to use stairs.

Our second aim was to investigate the role of expertise in strategy choice as a way to gain insight into change mechanisms. To do so, we documented 13.5- and 18-month-old infants’ spontaneous navigation strategies for stair descent when they were placed at the top of a staircase and encouraged to make their way to a caregiver waiting at the bottom. This design allowed us to investigate emerging solutions at multiple time scales: Step by step, trial by trial, and between age groups (Adolph, Robinson, et al., 2008; Badaly & Adolph, 2008; Siegler, 1996). The stair descent task required infants to generate a goal (reaching a parent at the bottom of a staircase), sequence the steps necessary to obtain the goal (possibly devising alternative descent strategies for balance control), and continually monitor their progress towards the goal (to maintain balance). Each of these task components places a heavy demand on cognitive resources (Carrico, 2013). Moreover, younger infants would have little walking experience and little to no stair descent experience, so for them, the motor demands of the task would also tax attentional resources (Berger, 2004, 2010; Woollacott & Shumway-Cook, 2002). To lower their centre of gravity and increase control of balance, infants could theoretically choose alternative descent strategies such as scooting down on their bottoms facing forward or backing down stairs. However, despite the increased biomechanical stability associated with these alternative descent strategies, they are not initially found in infants’ locomotor repertoires (Adolph, Eppler, & Gibson, 1993). Infants who lack stair descent experience simply may not perceive these strategies as possibilities for action until they have amassed sufficient practice navigating stairs with their novice descent skills (e.g., Gibson et al., 1987; Kretch & Adolph, 2013). Examining patterns of infants’ choices and errors on the stair descent task speaks to the role of processing resources in the development of problem-solving in infancy.
Method
A subset of this data \((n = 19)\) was collected as part of a larger study examining the development of 13-month-old infants’ ability to inhibit. In the original study, infants descended a staircase several times before being encouraged to switch to a new staircase. Primary outcome measures focused on the differences between pre- and post-switch behaviours. Only data from the pre-switch trials were included in this data set. Data from the remaining participants (thirteen 13.5-month-olds and seventeen 18-month-olds) were collected specifically and uniquely for the current study.

Participants
Thirty-two 13.5-month-old infants (16 boys; \(M = 13\) months, 10 days; \(SD = 13\) days) and seventeen 18-month-old infants (seven boys; \(M = 18\) months, 1 day; \(SD = 7\) days) participated in this study. The criterion for participation was being able to walk 10 feet (3.05 m) across the room independently without stopping or falling. We chose 13 months as the age for the younger group because at that age, most infants have minimal to no stair descent experience and because pilot testing confirmed that stair descent was a challenging motor task that elicited rich motor behaviours for that age group (Berger, 2010; Berger et al., 2007). We chose 18 months as the age for the older group because in a previous survey of over 700 families about their infants’ navigation of stairs, most infants had learned to descend stairs between 17 and 20 months (Berger et al., 2007). Families were recruited via a purchased commercial mailing list. All infants were healthy and born at term. The sample was approximately 1/3 White, 1/3 Hispanic, and 1/3 other, including parents who refused to report; was primarily of middle-class socio-economic status; and lived in the New York City metropolitan area. An experimenter interviewed parents about infants’ crawling, walking, stair-climbing, and handrail experience (see Table 1). Interviewers used a strict protocol of probe questions regarding dates of events (Berger et al., 2007). Parents used ‘baby books’ or calendars to augment their memories for milestone dates. Families received a small thank-you gift and a diploma for participating.

Staircase apparatus
The experimental apparatus (see Figure 1) was a 54-cm-high wooden staircase with five steps down to the floor (step height = 14.29 cm) and custom-built low handrails (21.27 cm from the step) on both sides that came to approximately hip height on an average toddler. The top step (42 cm²) was wider than the other four (19 cm deep) so that participants would have room to maneuver if they wanted to change or explore positions before descending. Four poles at the corners (34.29 cm high) of the top step were available to provide support for balance while standing or shifting body postures before stair descent. All steps and risers of the staircase were carpeted.

Procedure
All participants completed five trials. At the start of each trial, an experimenter placed infants close to the centre of the platform, 15–20 cm from the edge. On each trial, infants descended the stairs to a caregiver who waited at the bottom. Parents called to their babies from the foot of the stairs and offered words of encouragement, but did not provide
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<th>13-Month-olds</th>
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<th>18-Month-olds</th>
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<td></td>
<td>Mean (SD)</td>
<td>Range</td>
<td>N</td>
<td>Mean (SD)</td>
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<tr>
<td>Walking experience</td>
<td>2 months, 5 days (27 days)</td>
<td>7 days–3 months, 16 days</td>
<td>32</td>
<td>5 months, 3 days (2 month, 2 days)</td>
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<td>Ascent experience</td>
<td>2 months, 26 days (1 month, 22 days)</td>
<td>7 days–6 months, 25 days</td>
<td>25</td>
<td>4 months, 17 day (2 months, 14 days)</td>
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<td>Descent experience</td>
<td>1 month, 28 days (1 month, 10 days)</td>
<td>3 days–4 months, 7 days</td>
<td>11</td>
<td>4 month, 26 days (3 months, 15 days)</td>
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<td>Number of infants with Stairs in the home</td>
<td>9</td>
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<td>Prior handrail experience</td>
<td>7</td>
<td>12</td>
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A highly trained experimenter spotted the infants by following alongside them to ensure their safety, but did not otherwise help the infants with descent. The experimenter held their hands near the infants to spot them, but did not touch them unless they started to fall. The session was videotaped with a single camera that captured each trial with a point of view of slightly above and facing the participants as they descended the stairs. Sessions lasted 30 min.

Results

Data coding
Data from each test session were coded from videotape using OpenSHAPA, a computerized video coding system (now Datavyu, datavyu.org; Sanderson et al., 1994). Toddlers contributed five trials each, yielding 245 total trials for coding (160 from 13.5-month-olds and 85 from 18-month-olds). A primary coder coded all outcome measures from video. To ensure inter-rater reliability, a second coder independently coded 25% of all outcome measures. Inter-rater agreement ranged from 0.98 to 1.0, and p-values for all Cohen's kappa coefficients < .01.

Variability in descent strategies
Coders documented all strategies infants spontaneously used to descend the staircase. Infants descended the stairs in three ways: Walking if they walked down the stairs, scooting if they bumped down the stairs on their bottoms, and backing if they moved backwards on hands and knees down the stairs. Infants could perform more than one descent strategy on each trial. A 5 (trial) × 5 (step of the staircase [top step to bottom step]) × 2 (age group) repeated-measures ANOVA, with trial and step number as within-subjects factors and age group as a between-subjects factor, revealed no effect of trial on the frequency that infants walked down the stairs, but did show main effects for step of the staircase and for age, $F(1, 47) = 4.62, p < .04$ and $F(1, 47) = 6.47, p < .02$, respectively, and a significant quadratic effect of step, $F(1, 47) = 8.81, p < .01$, with
13.5-month-olds more likely to walk with each step and 18-month-olds less likely to walk with each step over the course of each trial (see Figure 2, filled markers). For walk frequency, post-hoc analyses of step of the staircase revealed that the effect was primarily driven by an increase in walking on the later steps for the younger infants.

A 5 (trial) × 5 (step of the staircase) × 2 (age group) repeated-measures ANOVA on the frequency that infants scooted down the stairs revealed no effect of trial, but did show main effects for step and for age, \(F(1, 47) = 8.88, p < .01\) and \(F(1, 47) = 10.35, p < .01\), respectively, and a significant quadratic effect of step, \(F(1, 47) = 6.94, p = .01\), with 13.5-month-olds less likely to scoot with each step and 18-month-olds more likely to scoot with each step over the course of each trial (see Figure 2, open markers). For scoot frequency, post-hoc analyses of step of the staircase revealed that the effect was primarily driven by a decrease in scooting from step to step as each trial progressed.

A 5 (trial) × 5 (step of the staircase) × 2 (age group) repeated-measures ANOVA revealed no main effects of trial, step, or group on the frequency that infants backed down the stairs because infants almost never did so \((n = 9\) trials). Thus, on most trials, infants performed 1 or 2 strategies, although one infant did perform all three strategies on a single trial.

**Role of experience on stairs**

Because the way in which infants executed a descent strategy is likely due to their proficiency navigating stairs, as well as their planning skills (van der Meer, 1997), we examined whether infants’ experience on stairs prior to visiting the laboratory was relevant. Calculating infants’ stair experience was not as straightforward as doing so for other motor milestones. Typically, experience is operationalized as the number of days since an infant first performed a skill to criterion. However, in interviewing parents about their children’s experiences with stairs, parents often reported that infants may have demonstrated their ability to ascend or descend a staircase, soon after which the parents restricted access to only that one time. Thus, unlike days since the onset of walking or crawling, days since the first ascending or descending may not reflect an accrual of practice (Berger et al., 2007). In an attempt to more accurately capture infants’ actual descent experiences on stairs, we categorized infants as having no experience with stairs (no stairs at home, never gone down stairs; \(n = 21\)), some experience with stairs (stairs at

![Figure 2](image-url). Effects of step, trial, and infants’ age on descent strategy choices: Walking (filled circles), scooting (open circles), or backing (no markers).
home, but never gone down, \( n = 12 \); or no stairs at home, but has gone down, \( n = 5 \), or full experience with stairs (stairs at home, has gone down stairs; \( n = 11 \)).

**Using handrails**

Light touches of a handrail can augment balance and provide postural support (Barela, Jeka, & Clark, 1999; Chen, Metcalfe, Chang, Jeka, & Clark, 2008; Metcalfe & Clark, 2000), and experienced walkers can use handrails as a tool for balance control during locomotion (Berger & Adolph, 2003; Berger et al., 2005). We coded whether infants touched the handrail during stair descent. A \( 5 \) (trial) \( \times \) \( 2 \) (age group) \( \times \) \( 4 \) (experience on stairs) repeated-measures ANOVA on the proportion of trials that infants used the handrail revealed a significant main effect for age, with 18-month-olds using the handrail on 92% of trials and 13.5-month-olds using the handrail on only 57% of trials, \( F(1, 42) = 9.57, p < .01 \).

**Using the experimenter**

Coders documented the ways that the experimenter interacted with the infants as they descended the stairs. We counted rescues whether the experimenter had to touch infants to prevent them from falling as they descended. A \( 5 \) (trial) \( \times \) \( 5 \) (step) \( \times \) \( 2 \) (age group) \( \times \) \( 4 \) (experience on stairs) repeated-measures ANOVA on the proportion of trials that the experimenter rescued the infants revealed main effects for step, \( F(1, 42) = 6.54, p < .02 \), age group, \( F(1, 42) = 33.30, p < .01 \), and a step by age group interaction, \( F(1, 42) = 5.66, p < .03 \). 13.5-month-olds had to be rescued significantly more often than 18-month-olds, particularly at the end of each trial (see Figure 3, open and filled triangle markers).

We also coded whether infants used the experimenter to augment balance if they touched or grabbed the experimenter after they had left the starting platform. A \( 5 \) (trial) \( \times \) \( 5 \) (step) \( \times \) \( 2 \) (age group) \( \times \) \( 4 \) (experience on stairs) repeated-measures ANOVA on the proportion of trials that infants used the experimenter for support revealed a main effect only for experience on stairs, \( F(3, 42) = 3.06, p < .04 \) (see Figure 4a). Post-hoc analyses revealed that infants with the least experience (no stair descent experience, no

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**Figure 3.** Effects of step, trial, and infants’ age on the role of the experimenter: Used by infants to augment balance (circle markers), having to rescue infants when they started to fall (triangle markers), or not involved beyond spotting the infants (square markers).
stairs at home) and infants with the most experience (stairs at home, stair descent experience) used the experimenter significantly less often than infants with only moderate amounts of experience (all p’s < .05).

Finally, if neither the experimenter touched the infant nor the infant reached out to the experimenter for assistance, we coded that the experimenter remained uninvolved in infants’ balance as they descended, beyond simply spotting them for safety. A 5 (trial) × 5 (step) × 2 (age group) × 4 (experience on stairs) repeated-measures ANOVA on the proportion of trials that no touching occurred between the experimenter and the infant revealed a main effect for age group, F(1, 42) = 48.64, p < .01. Eighteen-month-olds ignored the experimenter significantly more often than the 13.5-month-olds did (see Figure 3, open and filled square markers).

**Latency**

Latency was defined as the time from the start of the trial (infants were placed in the centre of the starting platform, were on task directed to the goal, and were not held by an experimenter) until they took their first step off the platform and reflects the time it took infants to decide how to descend the first step of the staircase. Due to video equipment failure, latency is missing for two trials for one 13.5-month-old, who is dropped from the repeated-measures analysis.

A 2 (age group) × 4 (experience on stairs) ANOVA of infants’ mean latency to descend revealed a main effect for age and a significant interaction between experience and age, F(1, 42) = 5.90, p = .02 and F(2, 42) = 3.04, p = .05, respectively. As shown in Figure 4b, 13.5-month-olds tended to have longer latencies than 18-month-olds, but the difference between the groups is exaggerated for the most experienced infants, where 13.5-month-olds take more time to leave the starting platform than all other groups and 18-month-olds take less time than all other groups.

**Discussion**

This study examined the development of problem-solving strategies by microcoding how 13.5- and 18-month-old walking infants coped with stair descent in the laboratory. In the
tradition of using action to draw inferences about infants’ ‘hidden’ cognition (e.g., Keen, 2011; Oakes & Plumert, 2002; Piaget, 1954), our goal was to make the process of problem-solving observable. We documented the strategies that infants used to descend stairs and whether they modified their strategies from step to step as they descended a short staircase and from trial to trial over the course of the session. Infants’ descent behaviours in the laboratory were related to age and individual differences in stair experience outside of the laboratory. Of the three observed descent strategies, infants used walking and scooting most frequently; backing down stairs was rare.

Taking a microgenetic approach to understanding how infants solved the problem of stair descent revealed variability in infants’ descent strategies. Both age groups used multiple strategies within a single trial, usually switching between scooting and walking from step to step, but the pattern of strategy switching varied with age. As a group, most 13.5-month-olds (56–69%) tended to start each trial walking down the first step. However, over the course of the trial, the proportion of the sample choosing to walk down each step increased significantly (to 70–80% by the last step) and this pattern repeated anew for each of the five trials, as if being placed at the top of the platform was the start of an entirely new problem. The lack of learning from trial to trial played out as higher rates of walking and lower rates of scooting for the younger group at the end of a trial followed by renewed lower rates of walking and higher rates of scooting and ultimately a return to a greater likelihood of walking/lower likelihood of scooting by the end of the next trial. Given the proportionally greater height of the risers for the group, walking down stairs was a particularly bad choice for the 13.5-month-olds; they had to be rescued from falling down the stairs when they tried to walk. As a group, the 18-month-olds started each trial roughly split between whether they scooted or walked down the first step. Like the 13.5-month-olds, they renewed this pattern at the start of each trial. Unlike the 13.5-month-olds, however, they were more likely to scoot the rest of the way down the staircase.

Scooting lowers the centre of mass, in turn reducing the risk of toppling, but does require greater motor coordination and leg strength. It may be that only older infants had the strength and coordination to execute the scooting strategy or that the younger infants did not have the attentional resources to add an additional step to their motor plan or some combination of the two. Although parents report preferring their infants to back down stairs for safety reasons (Berger et al., 2007), and despite backing being an optimal biomechanical strategy for descent, it was an infrequent way for infants in both age groups to descend. Backing requires that infants inhibit being visually and motorically ‘captured’ by the goal so that they can turn away from it (Diamond, 1991; Lockman & Adams, 2001), counterintuitively move backward, and keep the goal in mind. However, children are heavily dependent on visual feedback for stair descent until age 4 or later (Cowie, Atkinson, & Braddick, 2010). Infants’ reliance on visual information during stair descent may have prohibited them from choosing backing as a descent strategy; anecdotally, the few infants who did back down the stairs turned their head to keep the goal in sight as they did so. Scooting may be a satisfactory compromise between the stability of backing and the visual information gained while walking, but was only a frequent descent strategy for the 18-month-olds. Newly walking infants may be so dependent on visual information during stair descent that they are more likely to choose a less stable stair descent strategy if it allows them to keep the stairs and the goal in view.

As new skills are acquired and mastered, variability in strategy use is typical (Adolph, Robinson, et al., 2008; Lemaire & Siegler, 1995). Understanding the pattern and trajectory of that variability helps us understand the process underlying acquisition of
problem-solving skills. In this study, scooting down stairs and using the handrail were alternative descent strategies that provided increased stability for toddlers. However, new walkers can be reluctant to switch to alternative locomotor strategies, even when continuing to walk means bumping a head on a low entrance or trying to squeeze through an impossibly narrow space (Berger, 2010; Berger & Scher, 2012; Brownell, Zerwas, & Ramani, 2007; Comalli & Adolph, 2013). In this case, for the few 13.5-month-olds who came up with the strategy of scooting at the start of the trial, maintaining that posture for the duration of the trial was difficult. In addition, the younger infants did not incorporate an external object into their action plan, with only around half of the group using the handrail, and almost none reaching out to the experimenter for help. The overlapping waves model of adaptive strategy choice would predict that with increased experience, the use of alternative strategies should increase (Lemaire & Siegler, 1995; Siegler, 2005). Indeed, the 18-month-olds, who on average had more walking and descent experience than the 13.5-month-olds, maintained the alternative descent strategy of scooting for a greater proportion of each trial and almost all used the handrail for support (they did not use the experimenter for help, either, but that was because they used the handrail instead). Moreover, infants with moderate amounts of experience reached out to the experimenter during descent more often than infants with no descent experience at all prior to participating in the study. Augmenting balance with an adult may serve as an alternative descent strategy available to infants with minimal experience on stairs that is less sophisticated than handrail use, but possibly reflecting prior experience in which an adult taught infants to descend.

A possible explanation for the observed pattern of strategy shifts could be the tendency of younger children to demonstrate ‘utilization deficiencies’ (Clerc & Miller, 2013; Gaultney, Kipp, & Kirk, 2005; Schneider, Kron, Hunnerkopf, & Krajewski, 2004). Utilization deficiencies were first identified by Miller (1990) as part of the normal progression of strategy development in which a strategy is used properly and spontaneously, but to no benefit. In keeping with the tradition of studying utilization deficiencies microgenetically (Coyle & Bjorklund, 1996; Schwenck, Bjorklund, & Schneider, 2007), we documented 13-month-olds’ tendency to switch to walking at later steps on a trial and the increased likelihood that they required rescue on those later steps. This pattern was parallel to the utilization deficiencies seen in tasks that traditionally study memory, selective attention, organization, and reading comprehension (Bjorklund, Coyle, & Gaultney, 1992; Gaultney, 1995; Gaultney et al., 2005; Miller, 1994). Consistent with Miller’s account of strategy development, 18-month-olds did not show evidence of utilization deficiencies – upon switching to a scooting strategy, they experienced the benefits that the younger infants did not – most likely due to their increased locomotor experience and greater pool of attentional resources.

Taken together, infants’ sequence of behaviours suggests that their exploration largely focused on how to approach the 1st step of the staircase, rather than on the creation of a detailed plan for navigating the staircase from top to bottom. For example, 13-month-olds typically started out with a good descent strategy, but soon switched to a bad one, with rescues happening primarily later in the trial. It is unlikely that this would be part of a general navigation plan given how effortful and taxing it is for new walkers to switch between postures (Berger, 2010) and how aversive they find being rescued from a fall (e.g., Adolph, 2000; Berger et al., 2005; Franchak & Adolph, 2012). Moreover, the 18-month-olds were essentially at chance in their choice of strategy on the first step, but consistently switched to a more efficient strategy for subsequent steps. If they were planning ahead from the platform, we might expect consistency in strategy choice from
the initial step, rather than settling on it eventually. Thus, it appears as though infants’ planning happened online as they faced the challenge of each new step, rather than at the start of a sequence of planned movements.

Individual differences in experience descending stairs also shed light onto the development of problem-solving. One of the hallmarks of expertise is understanding what information is relevant to the task at hand and how to use that information effectively (Adolph, Karasik, & Tamis-LeMonda, 2010; Tamis-LeMonda et al., 2008). Infants in both age groups who had the most experience descending stairs – having stairs at home and having descended stairs prior to visiting the laboratory – approached the problem of descent differently than infants with minimal descent experience. However, as with their choice of descent strategies, approach differed by age. Experienced 18-month-olds recognized the problem and quickly came up with a solution – they left the starting platform in a fraction of the time of all other groups. In contrast, experienced 13-month-olds took significantly longer to plan their descent strategy compared to all other groups. Their expertise gave them the wherewithal to recognize that they needed to plan their solution, but they were slower and more deliberate than the older infants in carrying out the plan. Both experienced groups’ exploratory behaviour suggested that they recognized stair descent as a novel problem and that their solution to this problem drew on their unique and specific experiences (van der Meer, 1997; Ulrich et al., 1990).

Adaptive locomotion involves both motor proficiency and higher level cognitive abilities (Berger & Adolph, 2003). Our microgenetic coding of strategy use, exploratory behaviour, and success on the task reflected elements of planning and decision-making associated with problem-solving. However, our measure of experience was admittedly a crude way to capture proficiency. For stair descent in particular, with only parent reports of the first day that infants performed the skill to criteria to go on, experience may be harder to measure than other motor milestones because of the inextricable role of parents creating constraints and opportunities for practice. The finding that our rudimentary measure of experience predicted one strategy suggests that it may be fruitful for future work to delve further into the role of proficiency with either biomechanical measurements or prospective documentation of stair experience. Previous work has shown that measures of locomotor proficiency predict individual differences when the locomotor task pushes infants to the limits of their abilities (Berger & Adolph, 2003). Our measure of experience may not have been sensitive enough to tease apart the contributions of skill and cognitive ability for all strategy choices, but a more precise measure may reveal a greater role of experience.

The development of strategy use has typically focused on older children learning to solve cognitive or reasoning tasks and has taken advantage of participants’ verbal abilities to respond to questions or provide commentary on their actions (e.g., Chen & Klahr, 1999; although Adolph, 1997; and McCarty, Clifton, & Collard, 1999; are some exceptions). One drawback has been the unsuitability of these methods for use with pre-verbal populations. In contrast, our approach to studying locomotor problem-solving has the advantage of documenting strategy use and decision-making in a younger population that is otherwise unable to comment on their own actions. We see striking parallels between infants’ behaviour in this locomotor problem-solving task and older children’s behaviour on more ‘cognitive’ tasks. For example, we got a glimpse of the first phase of strategy development, the acquisition of new strategies, with the appearance of new locomotor descent strategies in the repertoire of younger infants, and saw the utilization of new strategies in full force by the older infants. The second phase of strategy development is mapping prior experiences with strategies to the novel task. In this case, we observed the infants with
prior stair experience treating the laboratory task differently from the way infants with no or minimal experience treated the task. Finally, we observed phase three of strategy development, strengthening the newly acquired strategy. Over the course of several months spent acquiring relevant walking and stair descent experience, the older infants reified the more effective solutions to the problem of stair descent. Within each trial, we observed a mix of an initial failing to rely on newly acquired strategies, but then the strengthening of the usage of those strategies for the 18-month-olds.

These findings may be useful for parents whose children are learning to climb stairs. Previous work has shown that although infants’ may have locomotor expertise across a variety of terrains in one posture, they need to attain that expertise all over again upon the acquisition of a new posture (e.g., Adolph, 1997, 2000; Berger, 2010). Likewise, in this study, experienced walkers solved the novel problem of stair descent more effectively than novice walkers. Parents’ attempts to teach new, motorically safe, but cognitively challenging descent strategies to new walkers as they learn to descend stairs would be ineffective before infants have attained sufficient motor and cognitive proficiency. Parents’ vigilance upon the onset of infants’ acquisition of stair descent is crucial, particularly for new walkers.

Previous work has documented variability in locomotor strategies from trial to trial as new skills were acquired or revealed the repertoire of strategies available to experts (Adolph, 1997; Berger et al., 2005). Documenting descent strategy on a step-by-step basis in this study has helped to provide a new level of precision in understanding the process of acquiring the expertise required for successful strategy choice. As cognitive resources are taxed during a challenging task, performing the task itself may reduce the resources available for weighing alternatives or inhibiting an often-used strategy. On each trial, younger infants entertained an alternative, more stable strategy for descent (scooting), but often reverted to their typical locomotor strategy of walking before the end of the trial. During each new trial, they considered again the possibility of using a better, safer strategy, but the motor difficulty of stair descent combined with the cognitive demands of entertaining alternative plans of action may have overtaxed their resources. In contrast, the older infants who did not have to attend so closely to the motor demands of descent could more easily consider alternative strategies, including switching to scooting and using a handrail, and maintain those solutions over the course of a trial.

In sum, documenting within- and between-trial problem-solving at both microgenetic and cross-sectional levels in a locomotor task yielded a rich behavioural data set and helped to chart the process of becoming increasingly proficient and efficient in strategy choice and use. Studying learning in action demonstrated that stair descent requires problem-solving strategies similar to those previously observed in other forms of adaptive locomotion, as well as in tasks more broadly construed as cognitive (Berger, 2010; Berger & Adolph, 2007; Carrico, 2013).

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